# MICROPROCESSOR BASED DATA ACQUISITION AND CONTROL SYSTEM FOR REP-RATE HIGH VOLTAGE PULSED POWER INSULATION BREAKDOWN RESEARCH EXPERIMENTS*

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## I. Abstract

A specialized data acquisition and control system based on a microcomputer has been shown to be a feasible solution to the problems that arise in the measurements of repetitively pulsed high voltage in insulation breakdown experiments. This is to be compared with the high cost of commercial transient diagnostic systems and the limitations of manual test equipment. The system features data acquisition at a modest accuracy, control insuring the safety of the system and its users, and a relatively low cost.

Parameters which can be measured for repetitive rate breakdown experiments using this system include the dc supply voltage, output pulse width (at two variable levels) and peak voltage, and the number of pulses applied. A local trigger pulse of variable width and an enable line are available for system control. The software allows for rapid automatic decision making in the determination of breakdown.

## II. Introduction

There is a growing number of pulse power applications which require small, light-weight capacitors. In satellites and air-borne pulsed power devices, for example, there is a need for high frequency (> 100 Hz) and high discharge rate (< 1 μs) capacitors. High voltage tests are performed in order to develop a model of the breakdown phenomena of dielectrics which will help to satisfy this need. This model will allow a better understanding of the physical processes limiting lifetime and energy, and will allow useful predictions of these limits.

One experiment in dielectric capacitor development is the rep rate breakdown test. High speed transients and the relatively short time between pulses pose unique problems for data acquisition and control.

Currently, most measurements of the high voltage tests are made with manually operated test equipment such as oscilloscopes, voltmeters, and digital counters. All control and decision making, however, rests with the experimentalists. Visual interpretation of oscilloscope traces can lead to inaccurate data, and the reaction time of the operator may be too long to prevent some damage to the test equipment.

One solution to these problems is to use more elaborate, commercially available data acquisition systems. These systems can offer excellent digitizing rates, resolution, and the benefits of computer interfacing.

More advanced systems, however, may be unsuitable for a particular application. The cost can be prohibitive for the task to be done, approaching a half million dollars for some systems; and yet the system may not be adaptable to the application.

A feasible solution to these problems, the development of a cost effective, microprocessor based, automatic data acquisition and control system (DACS) for the rep-rate breakdown test is the subject of this paper. This development project is a more specialized application of a DACS than those currently available. This directed approach allows fewer components to be used, keeping costs low while still yielding modest speed, resolution, and accuracy in data acquisition.

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Control of the experiment is continuous and consistent, while measurements are autonomous, under general operator supervision. Computer software aids in quick decisions, performs first order control of the equipment, and allows user interaction.

## III. Background: HV Pulse Tests and Equipment Characteristics

Rep-rate voltage breakdown test experiments analyze the effects of pulse rise-time, width, amplitude, and repetition rate on the breakdown voltage. The relative life of the insulating material is measured by the number of pulses applied.

The equipment used for the rep-rate breakdown experiments include [1,2] a pulse generator supplying a variable frequency triggering source to a modified Model 9 Hard-Tube Pulser [1]. The modifications allow the output pulsewidth and leading-edge risetime to be varied. Table I shows the specifications of the system. The pulsewidth is controlled by the trigger pulse width.

A rep-rate breakdown experiment begins when the trigger pulse generator is turned on. The peak of the high voltage pulses is then raised continuously at a rate of 4 kV per second. When breakdown occurs, the trigger pulse generator is then turned off and the voltage removed.

TABLE I. HV Pulser Specifications.

| Parameter | Specifications |
|---|---|
| Output voltage | 0 to - 25 kV |
| Rated output | 40 A |
| Pulsewidth | 0.2 to 5 μs continually variable |
| Risetime | 50 ns to 5 μs |
| Repetition rate | 0 to 1700 pps, externally triggered |

Measurements are made using a high voltage probe, an oscilloscope, and a counter. Breakdown is determined when the voltage on the oscilloscope collapses, and the magnitude of the last voltage pulse seen before this is noted as the breakdown voltage. The number of pulses to breakdown, a measure of the lifetime of the sample, is recorded from the pulse counter.

There are, however, some problems with the manner in which the original Mod-9 was made to operate. It is a manual system requiring two operators, one to watch the oscilloscope and one to control the high voltage pulses. There may be a delay of as much as a few seconds between the time at which breakdown occurs, and when the high voltage pulsing is stopped by the operator via the trigger pulser. Due to this delay, there are thousands of arcs applied between the electrodes. These arcs cause pitting of the electrodes which will have to be reground and polished before use. This is to be avoided if a fast turnaround is to be accomplished. The system described here uses a computer to determine breakdown and control the experiment.

The exact shape of the HV pulse at or near breakdown for the rep-rate case is not known and will be a

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14. ABSTRACT
**A specialized data acquisition and control system based on a microcomputer has been shown to be a feasible solution to the problems that arise in the measurements of repetitively pulsed high voltage in insulation breakdown experiments. This is to be compared with the high cost of commercial transient diagnostic systems and the limitations of manual test equipment. The system features data acquisition at a modest accuracy, control insuring the safety of the system and its users, and a relatively low cost.**

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subject of investigation once computer control is operational. Figure 1 demonstrates four reasonable cases. The normal voltage pulse before breakdown is shown in Figure 1(a). Figures (b) and (c) demonstrate possible partial breakdown degradations of the voltage pulse at or near breakdown. After complete breakdown, the voltage pulse completely collapses as in (d).

One possible method to determine if breakdown has occurred is to measure the pulse width at two different voltage thresholds, and compare them. This is also shown in Figure 1 by HIGH $V_T$ and LOW $V_T$. If the pulse widths at the two levels are greater than zero and approximately equal (within resolution of system), breakdown has not occurred. If the pulse width at the HIGH (closer to peak) threshold is zero, or substantially less than the pulse width at the LOW threshold (closer to zero volts), then it can said that breakdown occurred. If the voltage pulse at breakdown is a short, square pulse, then case (d) will be detected after complete breakdown.

## IV. Microprocessor Based DACS

The DACS for the rep rate breakdown test consists of two basic parts: the COMPUTER, and the data acquisition and control INTERFACE. A block diagram of the DACS and the high voltage equipment is shown in Figure 2. The DACS was placed in a screen room to provide protection from RFI.

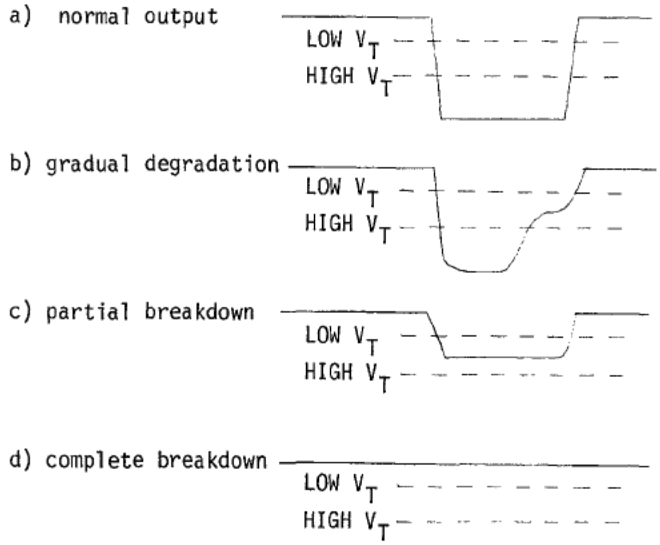


Figure 1. Possible cases of insulation breakdown. $V_T$'s represent voltage threshold on the pulse width measurement system.

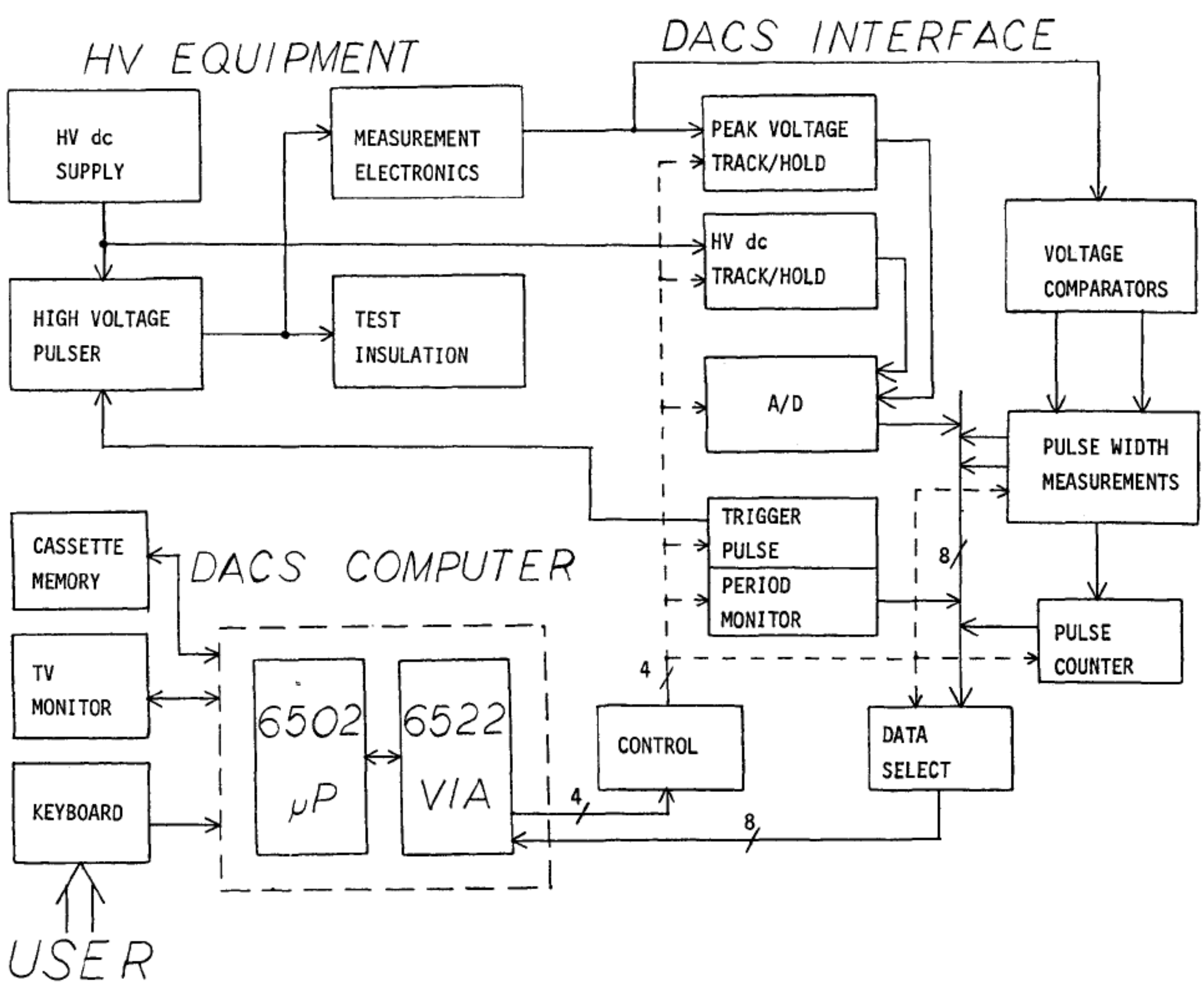


Figure 2. Block diagram of HV equipment, DACS computer and interface.

### Computer

AT the core of the computer system [3] is a Synertek 6502 microprocessor with 4 k bytes of RAM. All information transferred between the 6502 μP and the DACS interface is performed by a 6522 Versatile Interface Adapter (VIA). The VIA is a memory mapped parallel port interface IC. One of its ports is configured to output control information and the other to input data through a data selector.

Supporting peripherals include a standard keyboard and interface, a TV connection (for use as a monitor), and a serial I/O port to a cassette recorder for mass storage. Supporting software allows developing and debugging 6502 assembly language programming.

### Interface

The input signals to the interface, the HV output pulse and the dc supply voltage, are buffered by the high voltage probe and oscilloscope used for the original tests. The "Signal Out" connection from the Tektronix 1A1 Oscilloscope [4] plug-in unit provided the signals to the interface. The oscilloscope also allows the measurements of pulse width, peak voltage, and rep rate by the DACS to be checked.

Track and hold circuits capture the HV dc supply HV output pulse voltages for the A/D converter. The converter is an 8-bit, 8 multiplexed input ADC0809, with a full scale input of 5 V corresponding to 25 kV.

The output pulse is also sent to two digital comparators for pulse width measurement and breakdown detection. The comparator also strobes circuitry which counts the number of HV test pulses.

The μP controls the flow of digital data and the A/D converter, retrieving information asynchronously from the output of the pulser. A decision concerning breakdown is made, and the trigger pulse which strobes the HV pulse is controlled accordingly. The trigger pulse width is variable, and the trigger frequency is measured.

Each measurement unit is self-operating, monitoring and updating information after each pulse. This allows higher speed acquisition, more "free" time for the μP, and fewer hardware connections.

The circuit used to make measurements concerning breakdown is shown in Figure 3. This circuit is duplicated to give measurements at two variable levels of the peak voltage amplitude of the pulser output. The high speed LM361 comparator enables a 20 MHz signal to pass to a 74LS393 counter. The width of the high voltage pulse at each threshold is represented as a number of counts. The microprocessor reads and compares the two counts. Breakdown is said to occur when the value of the count at the HIGH level is less than 60% of the value of the count at the LOW threshold. The breakdown determination percentage can be changed in the software.

This circuit also provides time-out protection and updated measurements at each pulse. This is accomplished by using the two outputs of opposite polarity from the comparator, and two CD4017 decade counters with decoded decimal outputs.

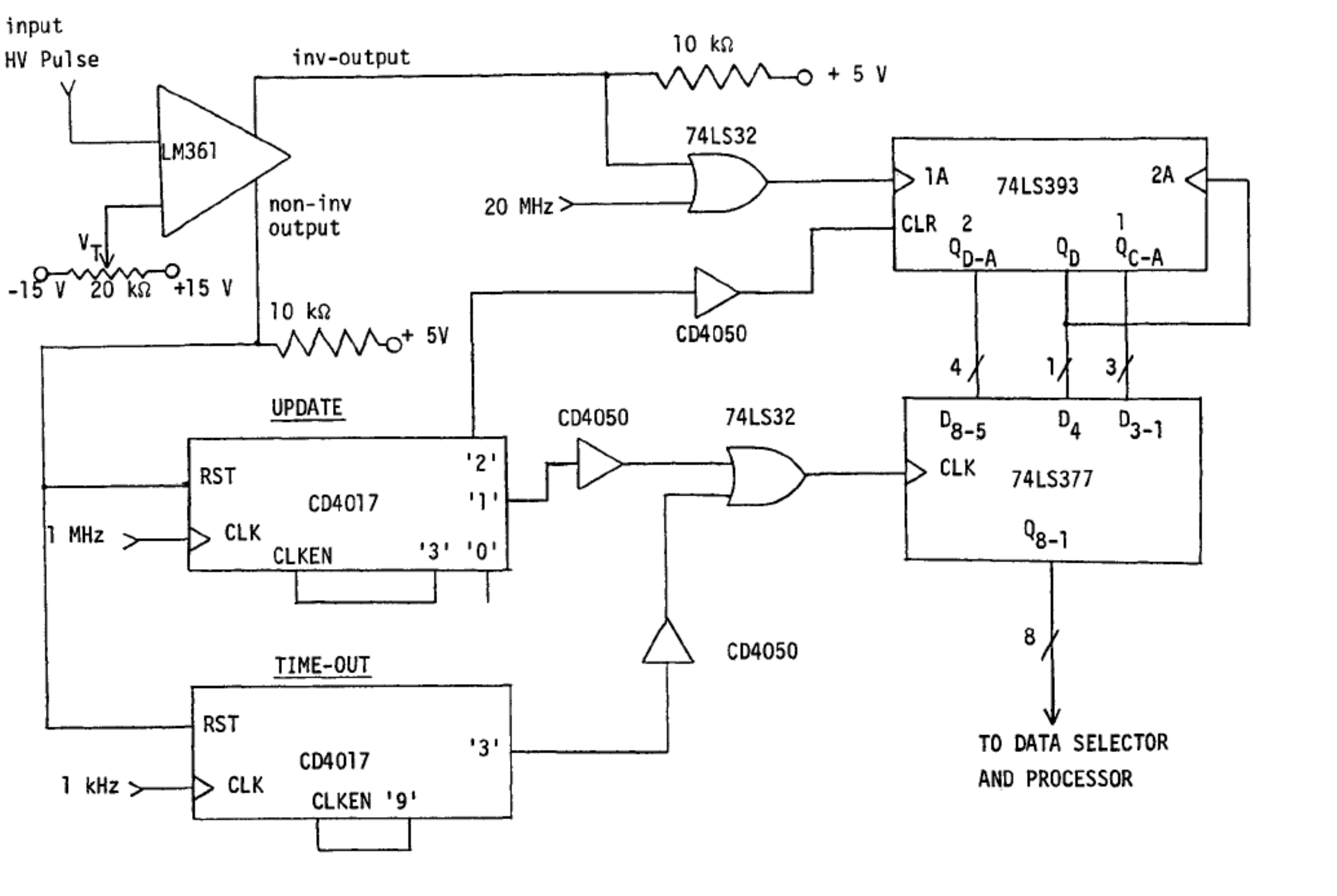


Figure 3. Pulse width measurement circuit for one threshold level of pulser peak output voltage.

While waiting for a pulse, the 74LS393 counter is set at zero, and the previous count is held in the 74LS377 latch. When a pulse occurs one comparator output (inverted) allows the 20 MHz pulse width signal to be counted. After the pulse, the pulse width counting is stopped, and the other (non-inverted) output allows the update and time-out counters to work.

The first clock to the update counter latches the new pulse width, and the second CLEARs the pulse width counter. The third clock is fed back and disables this counter, preparing the circuit for another pulse.

Note that for both thresholds a pulse width measurement is always available to be read by the processor. This will not change unless another high voltage pulse occurs. If the breakdown case in Figure 1(d) (voltage is immediately or always zero volts) occurs, the time-out counter will latch in a zero count to be read by the processor so that breakdown can be detected within tens of pulses. This fast turn off control action is a significant improvement over manual control.

## V. Summary of Performance Results

The measurement functions performed by the rep-rate DACS are:

1. Pulse width at HIGH and LOW Thresholds of the Mod-9 HV output pulse
   - o 0 to 12.5 μs
   - o 50 ns resolution
2. Counting the number of Mod-9 HV pulses applied to sample
   - o 0 to 268,435,456 pulses
3. Peak voltage of Mod-9 output pulse and
4. dc supply voltage of Mod-9
   - o 25 kV max = full scale input of A/D
   - o 0.1 kV = 1 bit resolution
5. Time between repetitive trigger pulses to Mod-9
   - o less than 4096 μs.
   - o 250 to 1700 pps (the limit of the Mod-9)

Each measurement unit is self-operating, monitoring and updating information after each pulse. Data is retrieved sequentially, asynchronously to the output of the pulser, by the processor.

The control functions performed are:

1. Detect breakdown via pulse width measurements and stop the trigger signal to stop the HV pulses.
2. Software controllable definition of breakdown.
3. Trigger pulse generation control of Mod-9 HV pulse
   - o 1 kHz repetition rate (present work standard)
   - o 0 to 12.5 μs width
   - o 0.1 μs resolution of pulse width
4. Manual START/STOP of trigger signal to Mod-9 through keyboard
5. Interactive keyboard access to system status
6. System is adaptable

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